Biomechanics & Gait

166

IN VIVO 3D KINEMATICS OF EARLY STAGE OSTEOARTHRITIC KNEES

K. Matsuki[1], K.O. Matsuki[2], T. Kenmoku[2], S. Yamaguchi[2], A. Watanabe[1], S. Ochiai[1], T. Sasho[2], Y. Wada[1], S.A. Banks[3]. [1]*Teikyo Univ. Chiba Med. Ctr., Ichihara, Japan;* [2]*Chiba Univ. Graduate Sch. of Med., Chiba, Japan;* [3]*Univ. of Florida, Gainesville, FL, USA*

Purpose: Knee osteoarthritis (OA) is one of the common musculoskeletal diseases among elderly population, and many studies have been studying its pathology including kinematics. 3D-2D model registration technique has been used for analysis of knee kinematics such as normal, ACL-deficient and implanted knees. Only one study employed this method to analyze severe OA; however, there have been no studies on early stage OA knees. The purpose of this study was to analyze kinematics of early stage OA knees using 3D-2D model registration technique.
Methods: Five patients with bilateral medial compartment knee OA were involved in this IRB-approved study. They were all female with a mean age of 52 years old (range, 43–57). They were confirmed with x-ray that they had grade 1 or 2 osteoarthritic knees according to Kellgren-Lawrence grading. There were no knees that showed clinically apparent dysfunction of the knee ligaments. Fluoroscopic images of pivot and squat activities were recorded at 30 Hz for both knees in each subject. CT scans of the knee were acquired with a 0.5 mm slice pitch, and 3D surface models of the distal femur and proximal tibia were created. Anatomic coordinate systems were embedded in each model according to reported conventions. The 3D position and orientation of the femur and the tibia were determined using model-image registration techniques (Figure 1).

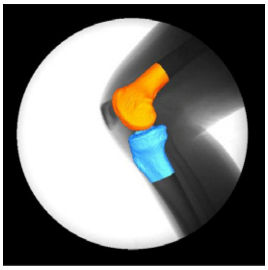

Fig. 1.

The accuracy of this method was 0.5 mm for in-plane translation, 1.6 mm for out-of-plane translation and 0.5 degrees for rotations. Knee kinematics were determined from the 3D position of each bone model using Cardan angles. Tibial anteroposterior translation and tibial internal/external rotation were used for analysis.
Results: During pivoting activity, the tibia translated 1.0 (SD 2.4) mm posteriorly and rotated internally 19.8 (SD 7.3) degrees (Figures 2 and 3). During squatting activity, the tibia translated 4.3 (SD 2.5) mm anteriorly and rotated internally 17.6 (SD 7.2) degrees (Figures 4 and 5).
Conclusions: A previous study on healthy knees that employed 3D-2D model registration technique has demonstrated that tibial anterior translation and internal rotation were 0 mm and 24 degrees for pivoting and 4 mm and 22 degrees for squatting. Rotational parameters in the

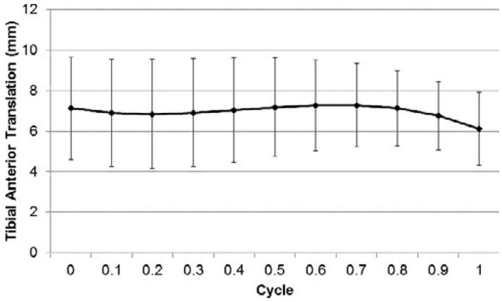

Fig. 2.

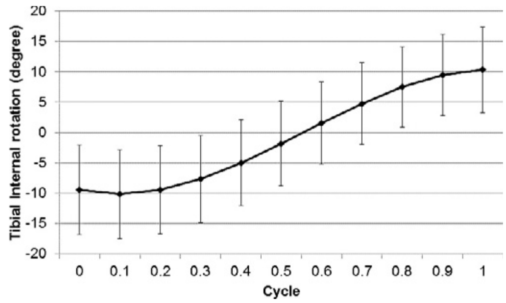

Fig. 3.

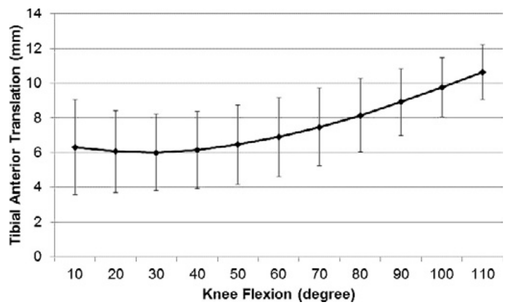

Fig. 4.

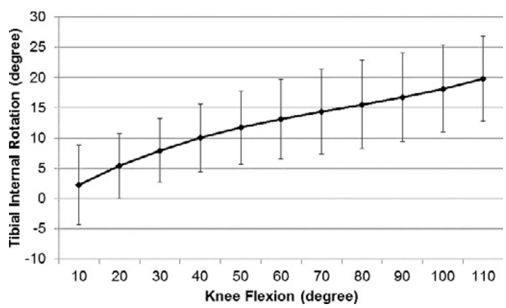

Fig. 5.

present study were smaller than the results of the previous study on healthy knees. Another study on severe OA knees has showed that tibial internal rotation was 11 degrees using same method. Internal rotation of the tibia during knee motion seemed to decrease with progression of OA. These changes in kinematics possibly have some influence on initiation and progression of knee OA.

167

THE INFLUENCE OF OBESITY AND ALIGNMENT ON KNEE JOINT LOADS DURING OSTEOARTHRITIC GAIT

S.P. Messier[1], M.L. Hoops[1], R.F. Loeser[2], C. Legault[2], R. Holt[2], P. DeVita[3]. [1]*Wake Forest Univ., Winston-Salem, NC, USA;* [2]*Wake Forest Sch. of Med., Winston-Salem, NC, USA;* [3]*East Carolina Univ., Greenville, NC, USA*

Purpose: The purpose of this cross-sectional investigation was to determine the influence of alignment and obesity on the knee joint loads of overweight and obese older adults with knee osteoarthritis. Our primary hypothesis was that there would be a significant interaction between knee alignment and Body Mass Index (BMI) on knee joint loads, independent of gender and walking speed.
Methods: Baseline data from a subset of participants (157 out of 454) enrolled in the Intensive Diet and Exercise for Arthritis (IDEA) clinical trial were utilized for this study. Knee alignment was quantified(N = 157)using a full length anteroposterior (AP) radiograph and categorized into three groups: varus (>2 deg.); neutral (0–2 deg); valgus (<0 deg). Internal knee moments, knee joint forces, and quadriceps, hamstrings, and gastrocnemius forces were calculated using a 3-D gait analysis with a 37-reflective maker set arranged in a Cleveland Clinic full-body configuration, a 6-Camera Motion Analysis system set to sample data at 60 Hz, and a torque-driven musculoskeletal model. Linear regression models were fitted for each kinetic outcome controlling for gender and walking speed.

Results: BMI ranged from 27 to 41 kg/m2 (mean = 33.4 kg/m2). Alignment distribution was: varus, 48%; neutral 27%; valgus, 25% (range: −11 deg valgus to 21 deg varus). After adjusting for walking speed and gender, there was not a significant interaction between BMI and knee alignment on the knee joint forces, or on the internal knee abduction moment. However, alignment had a significant ($p < 0.0001$) association with the internal knee abduction moment, independent of BMI. BMI had significant associations ($p < 0.01$) with the peak knee compressive and shear forces and peak knee muscle forces, independent of alignment.
Conclusions: A higher BMI was associated with greater peak knee compressive, shear, and muscle forces, regardless of alignment, and alignment was associated with the internal knee abductor moment, independent of BMI. Hence, BMI and alignment influence different joint loading measures that have both been linked to disease progression.

168
INCREASED TRUNK LEAN GAIT MODIFICATION FOR MEDIAL KNEE JOINT LOAD REDUCTION IN PEOPLE WITH MEDIAL KNEE OSTEOARTHRITIS

M. Simic[1], M. Hunt[2], K. Bennell[1], R. Hinman[1], T. Wrigley[1]. [1]*Univ. of Melbourne, Melbourne, Australia;* [2]*Univ. of British Columbia, Vancouver, BC, Canada*

Purpose: To evaluate the immediate effect of varying amounts of lateral trunk lean gait modification on medial knee load, as measured by the external knee adduction moment (KAM), and on knee pain in individuals with medial knee osteoarthritis (OA). Influence of participant characteristics (knee mechanical alignment and WOMAC pain) and timing of peak trunk lean on load-modifying effects of trunk lean were also investigated.
Methods: People with clinical and radiographic medial knee OA were recruited (13F, 9M; age 68.4yrs±10.2; mass 78.3kg±16.1). Standard weight-bearing AP radiographs were used to confirm OA and evaluate mechanical knee alignment. Participants underwent 3-D gait analysis along a 10m walkway (8-camera VICON, 3 AMTI force plates) using a standard lower body Plug-In-Gait marker set, with three additional trunk markers (manubrium, spinous processes of T2 and T10). A repeated measures experimental study was conducted with four gait conditions (5 trials each). Following natural walking trials, a physiotherapist instructed participants to lean their trunk towards the symptomatic limb during ipsilateral stance. Real-time biofeedback of trunk lean was provided to participants via a projector screen placed at the end of the walkway. Biofeedback comprised of the frontal plane trunk angle as a scrolling trace, with a shaded target area for each modification condition. Trunk lean conditions were recorded at natural gait speed in random order, where participants attempted the following lean angles: small (6°); medium (9°); and large (12°). Knee pain during each condition was evaluated via an 11-point numeric rating scale. Measures of medial knee load, the knee adduction moment (KAM) peaks (early and late stance), and KAM impulse, were primary outcomes. Effects of the modification on load measures were evaluated using linear mixed models, with participants as the random factor and peak lean angle as the fixed factor. Interactions with the independent variable were used to assess contributions of participant characteristics (mechanical alignment and WOMAC pain) and timing of peak trunk lean to the extent of load reduction. Change in pain was evaluated using repeated measures analysis of variance.
Results: Participants successfully performed the gait modification to the desired amount (gait data shown in Table 1). Increased trunk lean reduced all KAM measures ($p < 0.001$), with larger lean angles achieving greater reductions (early stance peak $F=107.6$; late stance peak $F=129.5$; and impulse $F=264.5$). Efficacy of joint load reduction was improved by an earlier peak trunk lean for early stance KAM and impulse ($F=5.21$, $p=0.02$; $F=10.37$, $p=0.001$ respectively), and a later peak lean for late stance KAM ($F=6.32$, $p=0.01$). Participant characteristics did not influence load-reduction and there was no change in pain across test conditions ($p > 0.05$).
Conclusion: Increased lateral trunk lean is an easily implemented gait modification that reduces medial knee load. A dose-response relationship between trunk lean and load reduction was found. Results suggest that timing of lean should coincide with peak knee loading to optimise load reduction. This modification did not immediately influence knee symptoms. Further research should determine if longer-term implementation can modify symptoms and structural disease progression.

Table 1. Descriptive data relating to natural gait and lateral trunk lean gait conditions

	Natural Gait	Attempted 6° lean	Attempted 9° lean	Attempted 12° lean
Lateral trunk lean				
Peak lateral trunk lean angle (°)	2.04 (0.32)	6.12 (0.31)	8.74 (0.31)	11.14 (0.31)
Timing of peak trunk lean (%stance)	51.55 (2.36)	37.72 (2.29)	37.66 (2.29)	38.49 (2.30)
Trunk lean at early stance peak KAM (°)	0.85 (0.39)	5.09 (0.38)	7.55 (0.38)	9.26 (0.38)
Trunk lean at late stance peak KAM (°)	0.84 (0.45)	3.01 (0.44)	4.38 (0.43)	5.56 (0.44)
Gait Characteristics				
Speed (m/s)	1.24 (0.04)	1.25 (0.04)	1.24 (0.04)	1.23 (0.04)
Knee Load				
Early stance peak KAM (Nm/Bw*Ht%)	3.75 (0.24)	3.40 (0.24)	3.33 (0.24)	3.19 (0.24)
Timing-early stance peak KAM (%stance)	26.59 (0.83)	25.20 (0.80)	25.10 (0.80)	24.58 (0.81)
Late stance peak KAM (Nm/Bw*Ht%)	2.05 (0.19)	1.71 (0.19)	1.69 (0.19)	1.56 (0.19)
Timing-late stance peak KAM (%stance)	77.74 (1.70)	77.05 (1.67)	77.76 (1.66)	77.68 (1.67)
KAM Impulse (Nm.s/Bw*Ht%)	1.22 (0.11)	1.05 (0.11)	1.03 (0.11)	0.96 (0.11)

169
CHANGES IN PERIARTICULAR MUSCLE ACTIVATION PATTERNS DURING WALKING ARE CONSISTENT WITH PROGRESSIVE STRUCTURAL CHANGES IN KNEE OSTEOARTHRITIS SEVERITY

D. Rutherford, C. Hubley-Kozey, W. Stanish. *Dalhousie Univ., Halifax, NS, Canada*

Purpose: Knee osteoarthritis (OA) is considered a failure of joint structure that can have considerable affects on joint function. Radiographic scoring based on the Kellgren-Lawrence ordinal scale (KL-scores) has been used to identify progressive structural alterations and subsequent disease severity. While differences in neuromuscular patterns have been previously reported between asymptomatic individuals and those with moderate versus those with severe OA, no study has looked at whether these changes occur along a disease spectrum within a mild to moderate OA grouping. This study tested the hypothesis that amplitude and temporal periarticular muscle activity characteristics would be altered with disease presence and in a progressive manner with knee OA radiographic severity.
Methods: After obtaining informed consent, four groups were identified: 35 asymptomatic subjects and 82 patients with medial compartment knee OA (38-KLII (mild), 33-KLIII (moderate), 11-KLIV (severe moderate)). Subjects were excluded if they were unable to perform a series of functional tasks and were scheduled for total knee athroplasty. A single experienced, blinded observer assigned KL-scores using standing anterior-posterior and lateral radiographs. Surface electromyographic (EMG) recordings were acquired from the lateral and medial gastrocnemius, vastus lateralis, medialis, and rectus femoris and the lateral and medial hamstrings using an AMT-8™ EMG measurement system (Bortec Inc.) during walking at a self-selected velocity using standard procedures. EMG signals were corrected for resting subject bias, gains, full wave rectified, low-pass filtered (Butterworth-6 Hz), amplitude normalized using the maximal voluntary isometric contraction method and time normalized to one complete gait cycle. Principal Component Analysis extracted predominant amplitude and temporal waveform features that together explained greater than 90% of the waveform variability for each muscle group. ANOVAs tested for main effects and interactions (alpha = 0.05). Post hoc testing was employed using Bonferroni procedures.
Results: Walking velocity and age were similar between the four groups. Body mass index and Western Ontario McMaster Osteoarthritis index (WOMAC) scores were similar among OA groups. Three features for each muscle grouping explained over 94% of the waveform variance. Significant group main effects ($P < 0.05$) were found for all three quadriceps PP-scores, for two hamstrings PP-scores and for one gastrocnemius PP-score. For all other scores significant group by muscle interactions ($p < 0.05$) were found. Post hoc testing revealed differences associated with disease presence and among disease severities. Specifically, medial gastrocnemius, lateral hamstring and